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RECRUITING RESOURCE AND GOAL ALLOCATION DECISION MODEL.(U)
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RECRUITING RESOURCE AND GOAL ALLOCATION DECISION MODEL

By

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January 1980

Final Report

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NOTICE

This final report was submitted by Occupation and Manpower Research Division, under project 2077, with HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235. Mr. Larry T. Looper was the Principal Investigator for the Laboratory.

This technical report has been reviewed and is approved for publication.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents an attempt to construct a mathematical model that could be used to allocate Air Force recruiter effort based on recruiting organization and demographic data available at the Air Force Recruiting Office level. Such a model based on a non-linear market response function and a dynamic programming allocation routine was developed and tested with actual Air Force data. The model was one already formulated and tested in a sales force marketing environment. With the aid of the model designer, it was modified to meet Air Force Recruiting Service needs and data availability. The model has been further modified to include several Recruiting Service organizational requirements. Validation of the model against actual Recruiting Service allocation decisions was performed and model resource allocations were very close to management decisions. Suggestions as to management use of the model in forecasting and recruiter productivity are also made in the report.

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I. BACKGROUND

This report discusses a research effort conducted by the Air Force Human Resources Laboratory (AFHRL) in support of a formal request by the Market Analysis Directorate of the Air Force Recruiting Service. The request was to conduct a research program exploring the possible uses of mathematical algorithms and allocation techniques to serve as aids in the resource and goal allocation decision process,

The initial phase of this project involved the examination of the applicability to the Air Force recruiting problem of the non-linear regression/dynamic programming allocation model developed by Beswick, 1973. Under contract, Dr. Beswick assisted in the application of his model and provided much invaluable technical input to the research and the writing of this report. The model, after it was delivered to AFHRL, was considerably modified with respect to both function and output. These changes resulted from suggestions made by the Air Force Recruiting Service.

Currently, the model is being further tested with guidance from the Recruiting Service. The crucial area of data determination and collection is in a state of flux, and of course, any validity or reliability of the model depends on having an accurate, relevant, and up-to-date data base. Closely related to this line of research is a contractual effort supported by AFHRL which is attempting to take a different approach toward the resource and goal allocation problem. In that contractual effort, a Markov-type probability state flow model is being developed as a decision aid, and a prototype model should be completed by December 1979. This report will concentrate on the need for, the development of, and the use of the model developed at AFHRL (using Beswick's model as a prototype) as part of the overall effort to meet the needs of the Recruiting Service.

II. NEED FOR THE RESEARCH

The reality of the All-Volunteer Force and the accompanying decreased benefits available to enlistees (e.g., the "G.I. Bill"), along with strong recruiting efforts by other services, require the Air Force to consider carefully the most efficient use of all its resources in order to attain the force posture levels necessary to carry out its mission. The primary resource is manpower and its allocation. The size and scope of Recruiting Service operations (some 1,600 recruiters and 1,000 officers) make it imperative that at least one type of quantitative tool be analyzed to determine its applicability in making the resource and goal allocation decision.

Such a need does not mean that no previous work exists in this field or that the Air Force does not currently use any formal method. On the contrary, Bennett and Haber (1972, 1973, 1974), Kelly (1972), Babiskin, Grissmer, and Sterrett (1974), and Hamblin (1974) have explored factors relevant to Army and Navy recruiting resource allocation, especially that of recruiter themselves. Arima (1976, 1978a, 1978b) has performed an excellent systems analysis of Navy recruiting, and his recently-published study (1978a) looks at the effectiveness of Navy advertising.

The Air Force itself is using a well-developed, formal approach to the determination of recruiting goals. The model and the goals for all its various recruiting programs are published periodically in the Air Force Recruiting Service Market Analysis Handbook. The approach is a straightforward linear regression, but it does not attempt to directly allocate resources. The resource allocation decision is made at several organizational levels based on on-site visits and other recruiting data collected by Recruiting Service.

The increasingly stringent budget limitations being placed on the Air Force make it imperative that methods be utilized which will result in more efficient allocations and more effective attainment of goals. This report presents a decision model developed for Air Force Recruiting Service and discusses its use as a decision aid in making the following decisions:

1. Recruiter Allocation
2. Total Recruiter Strength
3. Office Location and Boundaries
4. Assignment of Recruiting Goals
5. Forecasts and Performance Evaluation

III. DEVELOPMENT OF THE RESPONSE FUNCTION

In the most general sense, the task of an Air Force recruiter is one of "selling" the Air Force to prospective enlistees. Like private-enterprise sales personnel Air Force recruiters have many administrative matters to handle, but just as their civilian counterparts, the Air Force recruiters' main job is contacting individuals (clients) about joining the Air Force. If Air Force recruiting is similar to commercial individual sales marketing, then some of the research on sales force allocation in the business world should be adaptable to the Air Force sales force decisions.

Each of these decisions is based on an understanding of how the recruit market *responds* to recruiting effort and what the determinants of this response might be. Sales force response functions are typically based on small segments of the market called control units. A control unit is the smallest sub-unit of the market used for analysis. Depending on the nature of the selling situation, it may be an individual customer, a group of customers, or a small geographic area. For the Recruiting Service, an ideal control unit might be the county or school district. Because of data availability, however, the model considered in this report is based on Air Force office structure. Estimation of a control unit's response to varying levels of selling (recruiting) effort presents a major challenge because response is influenced by a variety of interacting factors, including market potential, recruiting effort and experience. Air Force advertising effort, and other variables such as the economy.

Some sales force researchers have used subjective estimates to develop separate response functions for each control unit (Little, 1970; Lodish, 1971; Montgomery, Silk, & Zaragoza, 1971). Subjective estimates of sales response make allowance, at least implicitly, for the interacting factors just mentioned. Statistically developed multivariate response functions have been employed in the areas of setting sales force size (Lambert & Kniffin, 1970), evaluating salesman performance (Cravens & Woodruff, 1973; Cravens, Woodruff, & Stamper, 1972), and in allocating selling effort (Beswick, 1977).

The way a control unit responds to recruiting effort is determined by the many interacting factors earlier. If the number of reservations is chosen as the measure of market response, the response relationship may be written in functional notation as:

$$R = f(E, W, M, A, X, PR, 0) \quad (1)$$

This is, response (number of reservations) in a control unit (recruiting office) is a function of recruiting effort (E), workload (W), market potential (M), advertising effort (A), recruiting experience (X), prior reservations (PR), and other variables (0).

Two fundamental problems face the researcher attempting to determine the *specific* function which describes office response. First, the choice of appropriate measures for the variables indicated in equation (1) is by no means obvious. For example, what measure should be used for

reservations: Should it be total reservations or net reservations (after training attrition) or quality reservations? Secondly, the problem of identifying the nature of the functional interaction between these measures is a difficult one: Which of the infinite number of possible functions f should be investigated empirically?

In particular, a specific functional form of equation (1) would be desired which would be applicable in a wide variety of situations and yet specific enough to incorporate knowledge gained from prior sales force work and from conceptual insights into the effectiveness of the recruiting decision variables in the context of Air Force recruiting (e.g., diminishing returns).

This report hypothesizes a functional relationship of the type described in the previous paragraph. This relationship is called the multiplicative factor model because it treats recruiting response as the product of a series of factors representing the relative strengths of the underlying causal variables of equation (1). This response function can be written as follows:

$$r_i = z_i t_i^a + C \qquad (2)$$

where

r_i = number of reservations in office i

z_i = f(W, M, A, X, PR, 0) as defined earlier in equation (1)

t_i = work-months of effort (E) in office i

a = response elasticity for E

C = constant term (from regression)

The effort factor (E) describes market response to recruiting effort; it is a response function of the general form shown in Figure 1, although S-shaped curves, or curves which decline beyond saturation levels of recruiting effort are also possible. When combined with the variables of z, as in equation (2), E defines an effort-response relationship which considers control unit differences in recruiting effort and in office and environmental variables (z) which are superimposed on the effort-response relationship be means of equation (2) to give a complete estimate of control unit response.

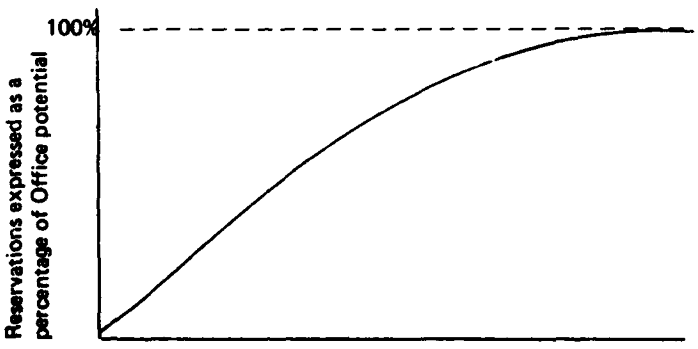

Figure 1. **Recruit market response to recruiting effort.**

Many data items and variables were examined as possible candidates for inclusion in the model of equation (2). It was decided to include all offices (subject to data availability) in building and testing the model. After merging data from several different sources, complete records were available for 807 offices. These offices were split into two groups: 538 were used to build the response function, and 269 were reserved for test purposes. Table 1 lists these data items and variable measures. Because of the basic functional form of the response function chosen in equation (2), non-linear regression analysis was then used to determine the precise functional form.

Table 1. **Variables Used in Model Development**

Factor	Variable	Definition
Performance	RES	Male Non-prior Service Reservations (April 77 – March 78)
Recruiting Effort	MME	Work-Months of Effort (estimate)
	RAS	Number of Recruiters Assigned
	RAUT	Number of Recruiters Authorized
Market Potential	HSM	Number of High School Seniors (Male)
	QUAL[a]	Percent Passing ASVAB [Armed Services Vocational Aptitude Battery] Mental Ability Test
	INT[a]	Percent Stating Interest in Military Career (ASVAB Test)
	UNEMP[a]	Percent Perceiving Difficulty in Employment (National Sample of 10,000)
	POP[a]	Population – Ages 16 to 21
	MINOR[a]	Minority Percent (ASVAB Test)
Advertising Effort	LEADS[a]	Number of Qualified Leads from National Advertising
	AFB	Number of Air Force Bases
Prior Experience (Reservations)	ACC	Male Non-Prior Accessions (April 76 – March 77)
Recruiting Experience	EXP	Average Recruiter Experience (Months)
Workload	SQMI	Square Miles Covered by Office
	NHS	Number of High Schools
	AHSS	Average High School Size

[a]These variables are available only by flight (i.e., data are not available at the office level).

In the initial stages of analysis, multiple linear regression was employed to investigate linear relationships among the variables in the data base and to aid in selecting variables to be included in the non-linear analysis. The complexities inherent in using a non-linear least squares procedure and the difficulty in using the program to select variables for inclusion in the model make it highly desirable to limit the number of variables analyzed by the procedure.

In an attempt to limit the variables, the first step in non-linear analysis was to use stepwise linear regression to analyze a logarithmically transformed version of equation (2). Although the models developed by this method may not be the best (in the least squares sense) fit of equation (2), they are close approximations to the best model, and it was felt that the capability of the stepwise procedure to select appropriate variables for inclusion in the model outweighed the non-optimal nature of the models developed. The Gauss-Newton non-linear least squares procedure was employed to develop the final recruiting response function which will be used in the decision analysis model for the Air Force Recruiting Service. This response function, which is the product of the non-linear regression analysis, is of the following form (variables are from Table 1):

$$R_i = (MME_i)^{.649} * 1.96(HSM)^{.13} * (INT)^{.14} * (AHSS)^{-.09} * (LEADS)^{.04} * (ACC)^{.69} * (EXP)^{.11} + 5.85(AFB) + 21.8 \quad (3)$$

Where:

1. The constant term value 21.8 has been added to improve the empirical fit of the multiplicative factor model. It simply raises the level of the entire response function shown in Figure 1 by a constant amount. Alternatively, it is the minimum number of recruits expected from any office.
2. AFB is included as a linear term because for many offices this variable is zero and hence is not suitable for inclusion in the multiplicative factor model. Other exogenous factors which affect only a limited number of offices could be treated in a similar fashion.
3. All of the multiplicative variables, except MME and HSM, have been indexed by dividing by the respective means for all offices; this allows reservations to be predicted under assumption of average levels of any of these variables by substituting a "1" for the indicated variable.
4. Only the variables indicated in equation (3) were investigated as part of the non-linear least squares analysis. Other variables were excluded from this final stage of analysis because they did not contribute significantly in the log-linear analysis or because they were highly correlated with another variable in the model (e.g., RAS was highly correlated with MME). The highest pairwise correlation between variables remaining in the model was .59 (MME, HSM).

The model given by equation (3) achieved an R^2 of .72. When model predictions for the test sample (269 observations) were compared to actual reservations, an R^2 of .68 resulted. These results are a good indication that the Multiplicative Factor Model does provide the estimates of market response necessary for quantitative analysis of recruiting service decisions and serves as proper input to the allocation phase of model development.

The problem of allocating recruiting effort for a fixed number of recruiters (N) can be formulated as follows:

$$\text{Maximize} \quad \sum_{i=1}^{n} r_i$$

$$\text{Subject to:} \quad \sum_{i=1}^{n} t_i = 12N \quad (4)$$

That is, maximize the total reservations in all n offices subject to the constraint that a fixed number of recruiters is available. This process can be repeated for increasing values of n until the total Air Force reservation goal for any recruiting program is reached. That is, repeat expression (4) for increasing n until

$$\sum_{i=1}^{n} r_i < G \quad (5)$$

where G is the goal for total reservations. Thus, this process will determine the minimum number of recruiters required to achieve a given reservation goal and will indicate how these recruiters should be allocated to offices.

Beswick (1977) describes a dynamic programming algorithm which can be employed to perform the procedure specified in the previous paragraph. This algorithm with several modifications was used to allocate recruiting effort for the 807 offices for which data were available. The total number of recruiters

was initially fixed at current levels. Model output for two squadrons (71 offices) is presented in Tables 2 and 3. The columns in these tables (from left to right) are the office, the work-months of recruiting effort for the current year, the optimum level of recruiting effort specified by the algorithm, the number of reservations predicted by equation (3) using the current level of effort, the number of reservations predicted at optimal levels, the actual reservations during the past year, the current level of recruiter strength, and the optimal levels of recruiter strength by office, flight, and squadron.

IV. USE OF THE MODEL

Several modifications were made to the model developed by Beswick (1977) to align it more closely to Air Force recruiting needs and to simplify its use as a problem solving and decision making tool. First, the model was made interactive via the use of a computer terminal. The model asks which of several recruiting accession programs the user is interested in studying. These accession programs are non-prior service male, non-prior service female, prior service male, prior service female. Officer Training School – male, Officer Training School – female, health services – doctor and health services – nurse. The Air Force has specific recruiting goals in each of these programs and also dedicates a portion of its recruiting force to each program.

The model then asks for the estimated number of recruiters, the recruiting goal for the particular program under analysis, and the number of recruiting offices. It should be noted here that the number of offices is fixed for any one model run. The allocation takes place among existing offices and is not concerned with opening new offices other than by indicating that certain areas need increased effort allocation. This will be seen in the output analysis section.

The user is then requested to input a factor of recruiting difficulty which is a perceived percentage of increasing or decreasing returns to recruiting effort, an upper and lower percentage limit on office manpower increase or decrease, and a percentage factor indicating amount of total recruiting effort spent on this accession program. After these data are input by the user, the model then performs the dynamic allocation and, upon completion, indicates to the user whether the goal could be achieved with the input number of recruiters or, if not, how many recruiters it would take to achieve the accession goal.

Once the model output is complete, the user may then examine the printout in office level, flight level, or squadron level form. As an example, consider the output presented in Tables 2 and 3 for Squadron 16 and Squadron 18, respectively. Squadron 18 shows an excess of 282 work-months (23 recruiters). Moreover, the response function predicts that if these changes can be implemented, 282 additional reservations (2271 – 1989) can be gained in Squadron 16, while Squadron 18 will lose 287 (2423 – 2136). Changes in expected reservations are always calculated between current and desired predicted reservations. Comparisons with actual figures can be misleading due to random model variation. Most importantly, the model output provides an office level analysis which can be used to plan these desired changes.

According to the model, office 16AA needs three more recruiters, while 16BE, 16BF, and 16CE should be considered as candidates for closings. Other Squadron 16 offices show substantial untapped market potential. The model indicates that at least double the current levels of effort is desirable in offices BA, BB, CC, CD, and EE.

While Squadron 18 shows the need for substantial net reduction in effort, there are still five offices (FC, FE, FG, FH and GB) which require at least one more recruiter. In general, though, most Squadron 18 offices require some reduction in effort levels and several should be considered as possible closeouts.

Many of the desired allocations can be achieved by reassigning or adding new recruiters as indicated previously. Another method is adjustment of office boundaries. This technique would, in

Table 2. **Office Level Analysis of Recruiting Effort – 1600 Recruiters**
(Squadron 16)

Office	Effort		Reservations			Recruiter Strength	
	Current	Desired	Current	Desired	Actual	Current	Desired
Flight 16A							
16AA	12	49	63	123	90	1	4
16AB	12	2	35	26	42	1	0
16AC	12	23	59	76	65	1	2
16AF[a]	10	19	48	62	57	1	2
16AG	6	5	33	32	32	1	0
16AH[a]	10	19	48	62	57	1	2
Totals	62	118	286	381	343	5	10
Flight 16B							
16BA	24	52	87	130	85	2	4
16BB	36	75	119	177	86	3	6
16BC[a]	20	17	61	57	59	2	1
16BD[a]	20	17	61	57	59	2	1
16BE	6	0	24	0	31	1	0
16BF	12	0	23	0	41	1	0
16BG	24	13	62	49	56	2	1
Totals	142	174	437	471	417	12	14
Flight 16C							
16CA	30	16	72	55	58	3	1
16CB	12	12	47	47	55	1	1
16CC	12	60	66	147	91	1	5
16CD	24	80	98	189	72	2	7
16CE	12	0	32	0	50	1	0
16CF[a]	18	31	67	86	65	2	3
Totals	108	199	381	523	391	9	17
Flight 16D							
16DA	46	42	114	109	139	4	3
16DB	12	10	45	43	44	1	1
16DC	24	10	58	42	73	2	1
16DD	24	13	62	49	55	2	1
16DE	18	9	51	41	58	2	1
16DF	12	20	51	63	35	1	2
16DH	12	3	38	28	30	1	0
16DI[a]	20	18	62	59	62	2	2
Totals	168	125	483	434	496	14	10
Flight 16E							
16EA[a]	16	26	62	77	66	1	2
16EB	12	0	22	0	58	1	0
16EC	14	10	54	49	75	1	1
16ED	12	12	47	47	41	1	1
16EE	32	77	113	182	113	3	6
16EH	18	4	44	30	46	2	0
16EJ[a]	16	26	62	77	66	1	2
Totals	120	156	402	462	465	10	13
Squadron 16 Totals	600	771	1,989	2,271	2,112	50	64

[a]These are new and contain flight-average data.

Table 3. **Office Level Analysis of Recruiting Effort – 1600 Recruiters**
(Squadron 18)

Office	Effort		Reservations			Recruiter Strength	
	Current	Desired	Current	Desired	Actual	Current	Desired
Flight 18A							
18AA	26	29	78	83	90	2	2
18AB	36	25	88	74	75	3	2
18AC	14	14	51	51	41	1	1
18AD	36	10	70	43	82	3	1
Totals	112	78	287	251	288	9	7
Flight 18B							
18BA	20	30	70	84	83	2	2
18BB	24	8	55	38	66	2	1
18BC	42	14	81	51	134	4	1
18BD	12	9	44	41	36	1	1
Totals	98	60	250	213	319	8	5
Flight 18C							
18CA	18	17	59	58	72	2	1
18CB	22	8	54	38	87	2	1
18CC	12	4	38	30	29	1	0
18CD[a]	16	7	47	36	55	1	1
18CE	12	0	26	0	34	1	0
Totals	80	36	224	162	277	7	3
Flight 18D							
18DA	24	8	55	38	57	2	1
18DB[a]	26	11	62	44	53	2	1
18DC	34	12	71	47	69	3	1
18DD	22	5	49	32	33	2	0
18DE[a]	26	11	62	44	53	2	1
18DF[a]	26	11	62	44	53	2	1
Totals	158	57	360	249	318	13	5
Flight 18E							
18EA	24	3	47	29	56	2	0
18EB[a]	18	5	46	33	39	2	0
18EC	14	4	41	30	28	1	0
18ED	20	2	41	26	19	2	0
18EE	24	14	64	52	65	2	1
18EF	12	0	26	0	31	1	0
Totals	112	29	264	170	238	9	2
Flight 18F							
18FA	52	39	119	102	95	4	3
18FB	24	11	60	44	72	2	1
18FC	36	82	122	192	61	3	7
18FE[a]	36	48	105	122	76	3	4
18FG[a]	36	48	105	122	76	3	4
18FH[a]	36	48	105	122	76	3	4
Totals	220	276	615	705	456	18	23
Flight 18G							
18GA	30	31	85	87	65	3	3
18GB	24	33	77	90	71	2	3
18GC	22	11	36	31	16	2	1
18GD	36	17	79	56	61	3	1
18GE[a]	28	19	72	61	53	2	2
18GF[a]	28	19	72	61	53	2	2
Totals	168	129	423	385	319	14	11
Squadron 18 Totals	948	666	2,423	2,136	2,215	79	55

[a]These offices are new and contain flight-average data.

effect, "create" new offices. For example, if 18GB and 18GC are adjacent, it may be desirable to move responsibility from GC to GB, thus increasing effort in GB while reducing the effort in GC by one recruiter.

Absolute agreement with desired effort levels is not necessary, and in some cases not even desirable. Small differences (1 or 2 work-months) between actual and desired levels of effort are relatively unimportant (as well as being difficult to eliminate). Large changes in effort may also be difficult to achieve in a short period of time, especially since Air Force policies (and common sense) preclude excessive numbers of recruiters at a specific location. (Note: This run was made with an unlimited increase in office strength, which was done only to show model global optimality.) These difficulties may prevent full achievement of optimal allocation and hence prevent achieving the increase in reservations predicted by the model, but it does not lessen the desirability of moving in the direction of model allocations.

Output from the allocation model provides a convenient worksheet which can be used to plan recruiting operations for the following year. The use of the model in allocation and office boundary decisions has been discussed previously. When these effort decisions (which may differ from the model's desired allocations as discussed previously) are entered as "current" levels, the model predictions will then represent expected reservations for the office given planned effort levels.

As the check of model validity, allocations for the 18th Squadron were compared with a recent staff report on these offices prepared after extensive field study and analysis. The detailed recommendations in this report were compared line by line with model output. In every office where a change was indicated, the direction of change suggested by the report was the same as the model recommendation. Changes in the magnitude of effort also concurred with model output, although in three offices where large changes were indicated, the staff recommendations were slightly more conservative than the model.

As for possible additional uses of model output, recruiting goal assignments could be determined through use of the predicted reservations based on management's planned effort level for that office. If the predicted level is below Recruiting Service's goal, then some adjustment, either through the goal or through increased manpower, should be made. In the area of performance evaluation, model predicted output could be compared with actual productivity by office. Of course, no individual recruiter data are in the model, so performance would be by office, flight, and squadron comparisons.

In both performance evaluation and goal assignment, it is advisable to adjust the goal or standard to reflect situations not considered by the model. This process involves managerial analysis and judgement of specific office situations and hence is time consuming. However, this type of involvement greatly enhances model effectiveness.

Total recruiter strength could be determined simply by setting model input parameters at various levels and "gaming" the model until the desired goal is achieved under various manpower and difficulty factors. Such factors could be exogenously determined by Recruiting Service management. As a forecasting tool, the model would use next year's *planned* effort levels to determine predictions and allocations.

V. CONCLUSIONS

Air Force Recruiting Service is strongly supportive of this model and its related research, as well as the contractual effort previously alluded to, which will enlarge the scope of the resource and goal allocation decision model. As a prototype, this model has been sanctioned by Recruiting Service. Data collection and especially data base update stand as major obstacles to its effective

utilization. It is believed, however, that with continued support such a quantitative scheme for assisting in the resource and goal allocation decision process is one viable means for meeting Air Force accession goals and assuring the ability of the Air Force to remain mission ready.

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